11. Simulating the state-by-state effects of terrorist attacks on three major US ports: applying NIEMO (National Interstate Economic Model)

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The Department of Homeland Security recently issued *Planning Scenarios* (Howe, 2004) that included preliminary estimates of the losses from various hypothetical terrorist attacks on selected major targets. There are three problems with many of these estimates:

- The orders of magnitude are often much too vague to be useful, for example, 'millions of dollars', 'up to billions of dollars'.
- The range and types of targets are too limited: many more than a dozen or so scenarios pose a serious economic risk.
- The geographical incidence of losses is not made clear, probably on purpose because of a policy decision not to identify specific target sites. 'All politics are local' may be a slight exaggeration, but decision-makers have a keen interest in the spatial incidence of possible losses.

Our research addresses all three of these problems. We have created what we believe to be the first operational interstate input–output (IO) model for the United States. The National Interstate Economic Model (NIEMO) provides results for 47 major industrial sectors for all 50 states, the District of Columbia, and a leakage region: 'The Rest of the World'. In the application reported here, we use NIEMO to estimate industry-level impacts from the short-term loss of the services of three major US seaports – Los Angeles/Long Beach, New York/Newark and Houston – on the economies of all 50 states and Washington, DC, as a consequence of hypothetical terrorist attacks. The seaports of Los Angeles and Long Beach are treated as one complex, LA/LB. Seaports in New York and Newark are also treated as a single port, NY/NJ. We treat the attacks on the three port complexes as alternatives rather than as simultaneous events.

In pursuing our research goals, the choice of approaches involved difficult trade-offs. The use of linear economic models is justified by several factors, including the richness of the detailed results made possible at relatively low cost. NIEMO, for example, includes approximately 6 million input–output multipliers. The principal insight that drives our research is that, with some effort, it is possible to integrate data from the Minnesota IMPLAN Group (MIG), Inc.'s IMPLAN state-level input–output models with commodity flow data from the US Department of Transportation's Commodity Flow Survey and with data from other related sources, making it possible to build an operational multi-regional input–output model.

In the sections that follow, we describe the steps involved in reconciling the information content in these data sources and making them compatible, integrating them to build NIEMO, and applying it to the problem at hand. The application also required the necessary multiplicands: What shares of local final demand do the temporary losses of port services involve? Finally, we discuss the nature of our results and some of the possible implications for homeland security policies.

BACKGROUND TO MULTI-REGIONAL IO CONSTRUCTION

Many economists and planners are interested in evaluating the socioeconomic impacts of business disruptions. Occasionally, they use geographically detailed input–output models. Isard (1951) demonstrated that traditional (national) IO models are inadequate because they cannot capture the effects of linkages and interactions between regions. To examine the full, short-term impacts of unexpected events such as terrorist attacks or natural disasters on the US economy, the economic links between states should be considered and accounted for. Multi-regional input–output models (MRIOs) include interregional trade tables and avoid some of the fallacies associated with aggregation (Robison, 1950). Building an operational MRIO for all the states of the US, however, requires highly detailed interstate shipments data.

Although Chenery (1953) and Moses (1955) had formulated a relatively simplified MRIO framework in response to the earlier discussions by Isard (1951), data problems persisted, and have stymied most applications. The non-existence or rarity of useful inter-regional trade data is the most problematic issue. Intraregional and inter-regional data must be comparable and compatible to be useful in this context, yet the currently available shipments data between states are only sporadically available and difficult to use.

It is not surprising, then, that few MRIO models have been constructed or widely used. The best known are the 1963 US data-sets for 51 regions and 79 sectors published in Polenske (1980), and the 1977 US data-sets for 51 regions and 120 sectors released by Jack Faucett Associates (1983), then updated by various Boston College researchers and reported in 1988 (Miller and Shao, 1990).

More recently, there have been two attempts to estimate inter-regional trade flows using data from the 1997 Commodity Flow Survey (CFS). The US Commodity Transportation Survey data on inter-regional trade flows have been available since 1977, but reporting was discontinued for some years. For the years since 1993, this data deficit can be met to some extent with the recent (CFS) data from the Bureau of Transportation Statistics (BTS), but these data are incomplete with respect to interstate flows. Based on the currently available CFS data, Jackson et al. (2004) used MIG, Inc.'s IMPLAN data to adjust the incomplete CFS reports by adopting gravity models constrained via distance and by making some additional adjustments.

Along similar lines and using the same basic data sources, we elaborate Park et al. (2004) who suggested a different estimation approach that relied on a doubly-constrained Fratar model (DFM). The Fratar model is an early transportation planning tool used to extrapolate trip interchange tables to reflect expected changes in trip ends. It is an intentionally naive numerical method requiring a minimum of assumptions. To proceed in this way, it was first necessary to create conversion tables to reconcile the CFS and IMPLAN (and other) economic sectors. This approach is elaborated in the sections that follow.

DATA

The primary requirements for building an interstate model for the US of the Chenery-Moses type are two sets of data:

- regional coefficients tables; and
- trade coefficients tables (Miller and Blair, 1985).

Models of this type can be used to estimate interstate industrial effects as well as inter-industry impacts on each state, based mainly on the two data sources:

- regional IO tables that provide intra-regional industry coefficients for each state; and
- inter-regional trade tables to provide analogous trade coefficients.

This implies the creation of three types of matrices:

- intraregional inter-industry transaction matrices;
- the inter-regional commodity trade matrix; and
- the combined inter-regional, inter-industry matrix, that is, a special case of an MRIO matrix, the core of the NIEMO model.

Before creating these matrices, however, the data reconciliation problem has to be addressed.

The main steps involved in building and testing NIEMO are shown in Figure 11.1. We developed a set of 47 industries, we call them 'the USC Sectors', into which many of the other economic sector classification systems can be converted. Figure 11.2 shows the state of our industrial code conversion matrix relative to the many data sources used in this study.

The detailed conversion processes occasionally involved case-by-case reconciliations of economic sectors. Inevitably, some conversions involved mapping one sector into more than one and vice versa. Some conversions required modifications with plausible weights extracted from ancillary data sources on a case-by-case basis.

Data for NIEMO Construction

The major problem in developing an interstate, inter-industrial model stems from the fact that it is difficult to obtain data describing trade flows between the states (Lahr, 1993). Since 1993, however, CFS data have been available for this purpose (Bureau of Transportation Statistics and US Census Bureau, 1999, 2000, 2003). Remaining problems with these data include high sampling variability or values omitted to avoid disclosure of individual company status. The existence of many unreported values has required relying on other data sources to approximate completeness of the CFS. It is not surprising, therefore, that there has been no comprehensive inventory of MRIO flows, since the work by Polenske (1980) and Jack Faucett Associates (1983).

The 1997 CFS reports trade flows between states for 43 SCTG sectors while the IMPLAN Total Commodity Output data-file includes their 509 sector values, available for all states. CFS includes the movement of foreign imports in its data as domestic movements. This means that all commodities coming into a US port are listed as outbound from that port

Table 11.1 Economic Data Sources and Associated Sector Classification Systems

Sector classification system	Economic data source					
	1997 Commodity Flow Survey (CFS)	2001 IMPLAN	1997 Bureau of Economic Analysis (BEA) Benchmark	2001 WISERTrade	2001 Waterborne Commerce of the US (WCUS)	2002 Economic Census
Standard Classification of Transported Goods (SCTG)	■					
Bureau of Economic Analysis (BEA)		■	■			
2001 IMPLAN		■				
North American Industry Classification System (NAICS)		■				■
Harmonized System (HS)				■	■	
Standard International Trade Classification (SITC)				■		
Standard International Trade Classification (SITCREV3-C)					■	
Waterborne Commerce of the US (WCUS)					■	

Source: Authors' construction.

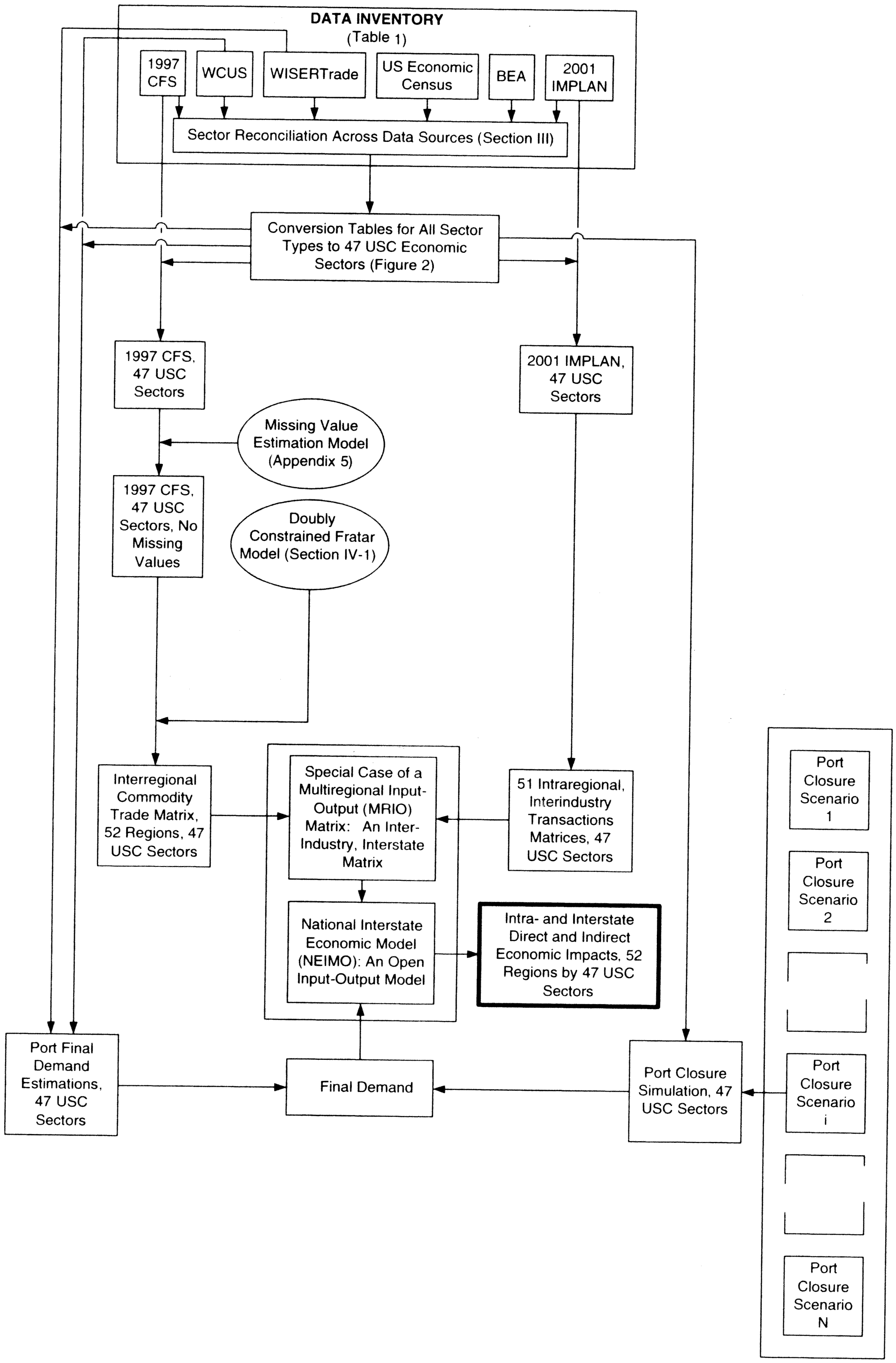


Figure 11.1 *NIEMO data and modeling steps*

Sector System	USC	SCTG	BEA	NAICS	IMPLAN (2001)	SIC	HS	SITC	WCUS
USC									
SCTG	*C, E*								
BEA	*C, E*	*C, E*							
NAICS	*C, E*	*C, E*	*A*						
IMPLAN (2001)	*C, E*	*C, E*	*A*	*A*					
SIC	*C, W*	*P*	*P*	*C, W*	*P*				
HS	*C, E*	*C, E*	*A*	*C, E*	*C, E*	*P*			
SITC	*C, W*	*C, W*	*P*	*P*	*P*	*P*	*C, W*		
WCUS	*C, W*	*C, W*	*P*	*P*	*P*	*P*	*C, W*	*C, E*	

Notes:
C: Complete mapping
A: Available from other sources
P: Possible to create mapping
E: Mappings constructed without any weights (Bayesian allocations)
W: Mappings constructed with plausible weights informed by additional data sources

Sector Classification Systems:
USC: USC sectors newly created
SCTG: Standard Classification of Transported Goods (http://www.bts.gov/cfs/sctg/welcome.htm)
BEA: Bureau of Economic Analysis (http://www.bea.doc.gov)
NAICS: North American Industry Classification System (http://www.census.gov/epcd/www/naics.html)
2001 IMPLAN: IMPLAN 509-sector codes
SIC: Standard Industrial Classification (http://www.osha.gov/oshstats/sicser.html)
HS: Harmonized System (http://www.statcan.ca/trade/htdocs/hsinfo.html)
SITC: Standard International Trade Classification available from WISERTrade (http://www.wisertrade.org/home/index.jsp)
WCUS: Waterborne Commerce of the United States (http://www.iwr.usace.army.mil/ndc/data/datacomm.htm)

Figure 11.2 Economic sector classification system conversions (current $)

and inbound to the next destination. Likewise, all commodities flowing to a port from anywhere in the US are outbound from the origin and inbound to the port. For these reasons, foreign imports in the 2001 IMPLAN data, which are available separately from domestic movements, are added to the IMPLAN Total Commodity Output tally.

NIEMO's inter-industry coefficient matrix is based on the commodity-by-industry version of the IMPLAN model. This is because the CFS trade matrix double- (or multiple-) counts commodities due to the movements of foreign imports to other states. We corrected these CFS multiple-counts by using the IMPLAN separate foreign imports movements values for commodities to improve the marginal distribution of the CFS matrix, and then re-estimated CFS entries to eliminate double- and multiple-counts.

In the current application, the 1997 CFS data were used as a baseline and updated to estimated 2001 values using 2001 IMPLAN data. The recent release of 2002 CFS data, to be matched to 2002 IMPLAN data, will simplify this approach in the near future.

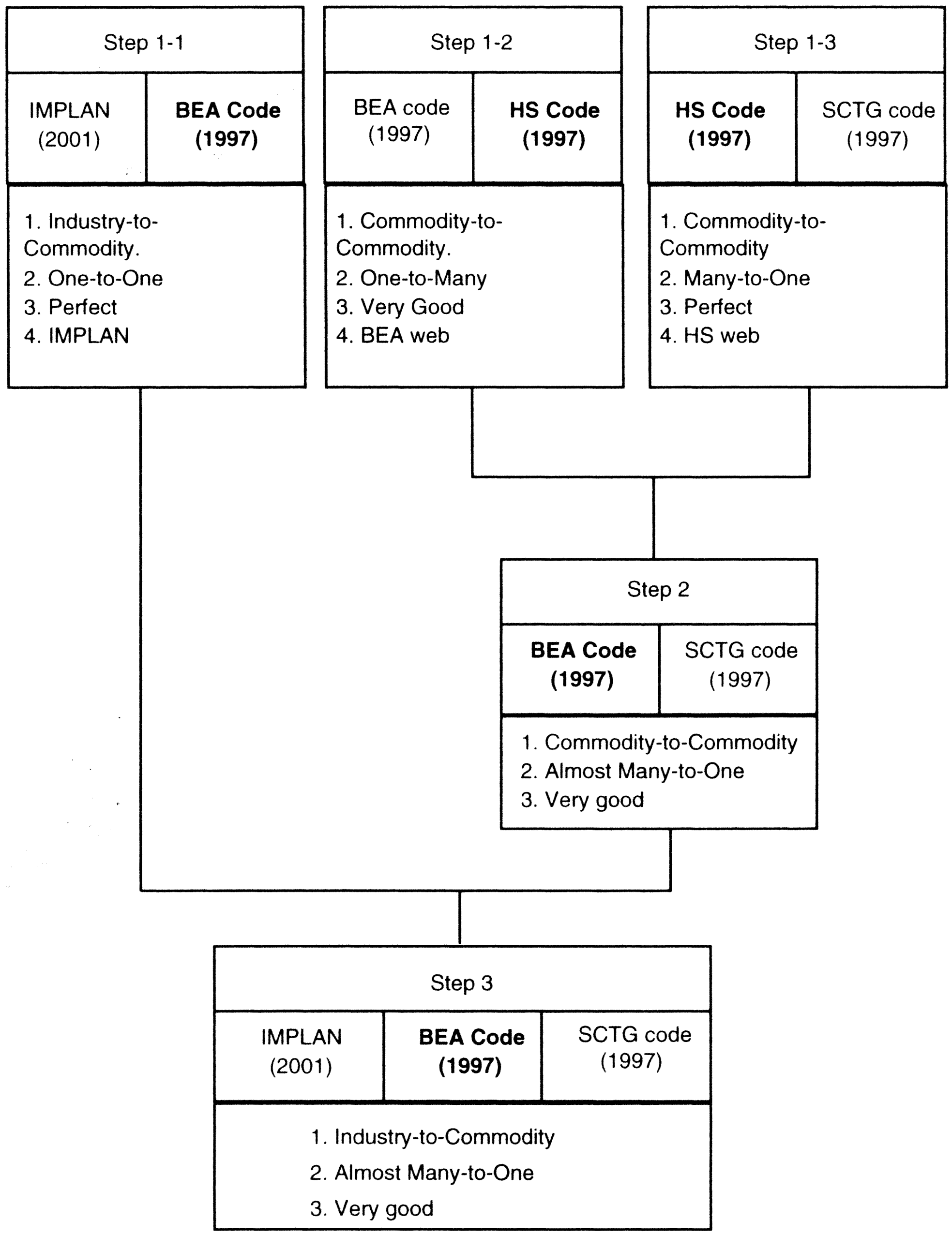
Differences between industry classification systems from different data sources make data reconciliation especially difficult in the absence of standardized and tested conversion procedures. The estimation of 2001 trade flows from 1997 CFS, therefore, required several intermediate conversion steps between the SCTG code systems used in the 1997 CFS and the IMPLAN system of sectors, not always one-to-one matched pairs.

Figure 11.3 shows the data reconciliation steps enabling the aggregation of 509 IMPLAN sectors to 43 SCTG sectors. (The steps involved in data reconciliation, the definition of USC sectors and the quality of results are described are available on the CREATE website.)

Multiplicands and NIEMO Tests

After estimating all the values needed to invert the 2444-by-2444 matrix, NIEMO can be used to simulate the loss impacts from hypothetical attacks on any major US target. In this research, we considered attacks on the three top US ports: the combined ports of Los Angeles/Long Beach (LA/LB), the combined ports of New York/Newark (NY/NJ) and the port of Houston. Together, these three facilities account for 38.1 percent of all foreign goods exports and 48.5 percent for foreign goods imports (Table 11.2).

The trade activities for the three ports, foreign and domestic by USC sector, had then to be estimated. WISERTrade processes and supplies data on foreign waterborne exports and imports for each US port, based on raw Census data. They do not include information on domestic waterborne



Notes:
Bold: Used as Reconciliation Code
1: Sector type
2: One = One sector, Many = Multiple Sectors
3: Quality of Reconciled Data
4: Sources and Abbreviations:
IMPLAN
BEA: Bureau of Economic Analysis (http://www.bea.doc.gov)
SCTG : Standard Classification of Transported Goods (http://www.bts.gov/cfs/sctg/welcome.htm)
HS : Harmonized System (http://www.statcan.ca/trade/htdocs/hsinfo.html)

Figure 11.3 Data reconciliation steps, SCTG and IMPLAN

Table 11.2 Top ten US ports: foreign exports and imports (current $ millions), 2001

2001 Rank	Ports	Exports	Ports	Imports
1	Los Angeles / Long Beach, CA	33 222	Los Angeles / Long Beach, CA	164 578
2	New York, NY / Newark, NJ	21 378	New York, NY / Newark, NJ	64 009
3	Houston, TX	21 241	Houston, TX	23 539
4	Charleston, SC	12 836	Seattle, WA	23 209
5	New Orleans, LA	10 951	Charleston, SC	20 876
6	Norfolk, VA	10 892	Oakland, CA	16 021
7	Oakland, CA	9 194	Baltimore, D	15 686
8	Miami, FL	8 846	Tacoma WA	13 943
9	Savannah, GA	6 544	Norfolk, VA	13 052
10	Seattle, WA	5 483	Philadelphia, PA	11 877
	Top ten US ports	140 587	Top-ten ports	366 790
	All US ports	198 841	All US ports	519 607
	Total US goods trade	718 762	Total US goods trade	1 145 927

Sources: WISERTrade data for ports and Table 1277, 2002 Statistical Abstract of the United States for Total US Goods Trade.

exports and imports. Because WISERTrade uses SITC codes for its seaport data, it was necessary to reconcile the USC Sectors and the SITC Sectors. A USC–SITC conversion table was created on the basis of three other conversion tables: USC–SCTG, SCTG–HS and HS–SITC. The USC–HS conversion was easily accomplished because the USC–SCTG and SCTG–HS conversion tables were already available from the NIEMO construction process (see Figure 11.3 again). After obtaining a conversion table for five-digit SITCREV3_C codes and six-digit HS codes from the Waterborne Commerce of the US (WCUS), and modifying the SITCREV3_C codes to four-digit SITC codes for each port, we created a new, weighted table converting four-digit SITC codes to six-digit HS codes. This enabled us to complete and use the USC–SITC conversion table.

Domestic seaborne exports and imports data are available from the WCUS files, which use their own classification code system based on SITCREV3_C codes. A limitation of the WCUS data is that the units reported are in short tons instead of dollars. We first changed the kilogram magnitudes in the WISERTrade data to short tons. Second, we created a conversion between WCUS and SITC using short ton values. Third, we created dollars-per-ton conversion tables for each port. We were then able to reconcile all the necessary seaborne trade data.

The results of these various reconciliations can be corroborated through foreign trade data comparisons between WCUS and WISERTrade. We found foreign trade for each port to be almost the same for each USC sector, regardless of data source. The results of our efforts to document all goods trade for the three ports are shown in Tables 11.3 and 11.4. These are the bases for our final demand calculations for each port, before we return to the construction of NIEMO.

CONSTRUCTING NIEMO

As noted above, constructing NIEMO required two basic tables:

- tables of intraregional industrial commodity trade coefficients; and
- a table of regional inter-industry transaction coefficients, as shown in Figures 11.4 and 11.5 respectively.

While trade tables by industry are hard to create because of incompleteness or unavailability of data, inter-industry tables are relatively easy to identify because reliable data are available from IMPLAN at the state and industry levels. To estimate NIEMO, we used the 1997 CFS data plus missing value estimates (all updated to estimate 2001 values) that include interstate shipments data for the 43 SCTG commodity sectors; and the corresponding IMPLAN inter-industry coefficients tables for each state.

Constructing Interstate Trade Flow Coefficients

Estimated 2001 commodity trade flows among all 50 states plus Washington, DC and the rest of the world were developed from the original 1997 CFS for 29 USC commodity sectors. We had to deal with the unfortunate fact that the 1997 CFS includes unreported values for a variety of commodities, including some marginal values such as total shipments originating in state i and total shipments destined for state j, and matrix cells representing commodity trade flows between pairs of states. The 2001 IMPLAN data report total origin and destination values by state. Hence, it follows that the 2001 commodity trade flows could be estimated with a Fratar model. However, the missing values in the 1997 CFS must be estimated first. Excel Visual Basic was used to develop the model to estimate these missing values and to execute the Fratar updates. In the future, we will develop an updated version of NIEMO based on CFS and IMPLAN data for the same year (2002).

Table 11.3 Final demand estimates for three ports ($ millions)

USC sectors	Final demand losses for export		
	LA/LB	Houston	NY/NW
USC1	110.624	21.030	11.381
USC2	159.524	107.081	21.710
USC3	167.088	10.684	30.129
USC4	9.808	6.059	5.297
USC5	83.475	74.997	31.179
USC6	17.957	1.186	1.584
USC7	28.533	0.020	1.372
USC8	12.280	4.839	26.128
USC9	5.535	2.312	2.503
USC10	444.812	431.543	1388.771
USC11	217.227	581.027	138.793
USC12	42.581	17.722	32.541
USC13	2.205	3.137	0.886
USC14	237.746	383.748	366.643
USC15	288.688	188.017	132.205
USC16	75.518	14.911	124.903
USC17	50.345	13.302	38.216
USC18	64.813	11.630	112.296
USC19	138.581	28.803	110.335
USC20	214.835	65.322	178.686
USC21	47.451	28.101	54.134
USC22	94.798	83.030	117.701
USC23	438.116	458.650	322.004
USC24	329.556	113.974	344.952
USC25	206.774	71.162	183.343
USC26	110.942	22.128	183.762
USC27	193.418	63.437	359.330
USC28	60.535	21.956	111.678
USC29	260.899	311.011	261.775
Export total	4114.665	3140.819	4694.239

USC sectors	Final demand losses for import		
	LA/LB	Houston	NY/NW
USC1	288.754	13.098	111.216
USC2	70.167	20.270	114.113
USC3	25.924	5.003	36.580
USC4	18.155	2.366	33.683
USC5	94.350	66.335	283.289
USC6	48.996	32.410	154.150

Table 11.3 (continued)

USC sectors	Final demand losses for import		
	LA/LB	Houston	NY/NW
USC7	5.495	0.052	1.616
USC8	3.413	6.170	15.853
USC9	0.719	2.164	3.176
USC10	517.640	1131.517	1057.081
USC11	227.362	448.906	266.429
USC12	13.060	12.166	86.791
USC13	0.318	4.397	0.491
USC14	209.201	153.954	345.002
USC15	553.886	44.776	187.790
USC16	150.895	30.173	65.337
USC17	74.408	10.020	57.535
USC18	86.941	9.965	73.560
USC19	2904.049	43.955	918.190
USC20	216.420	38.831	140.534
USC21	145.305	154.038	91.427
USC22	538.601	148.629	147.485
USC23	1054.568	202.517	493.051
USC24	3438.119	170.468	352.015
USC25	1504.472	135.470	878.226
USC26	49.591	16.342	118.430
USC27	346.843	47.903	224.694
USC28	660.672	27.757	195.007
USC29	973.274	239.684	247.142
Import total	14221.599	3219.337	6699.895

Fratar models are useful for estimating updated commodity trade flows; the starting matrices include numerous estimated values for missing entries in the CFS data. However, the traditional Fratar model calibrates only off-diagonal inter-regional cells. In this application, new diagonal values accounting for intrastate trade flows had also to be estimated.

We developed the doubly-constrained Fratar model (DFM), a new formulation that updates the diagonal values in the CFS matrix, and used the traditional Fratar model to estimate the off-diagonal values. Combining these two operations, the DFM iteratively estimates all the updated CFS values simultaneously and consistently. The estimated values for each USC sector are the base values for the next iterative step of the DFM.

Define ETO_i and ETD_j as the estimated values of TO_i, the Total Origin (Output) value for state i, and TD_j, the Total Destination (Input) values for

Table 11.4 Sum of intra- and interstate effects: three ports, shutdowns one-month ($ millions)

State	LA/LB	NY/NJ	Houston
AL	26.96	19.97	28.25
AK	3.08	13.65	1.05
AZ	53.69	7.86	19.53
AR	25.52	11.39	24.38
CA	2641.24	115.76	146.24
Direct_Impact_EXPORT	4114.66	–	–
Direct_Impact_IMPORT	14221.60	–	–
CO	31.40	12.35	21.87
CT	16.04	47.97	8.79
DE	5.08	6.85	2.58
DC	0.63	1.64	0.28
FL	31.23	36.37	24.32
GA	25.92	35.00	23.61
HI	5.40	7.99	0.94
ID	12.31	12.16	3.51
IL	70.84	48.25	53.94
IN	53.17	36.55	44.96
IA	36.06	28.55	12.81
KS	31.99	9.26	17.80
KY	29.16	55.69	25.42
LA	77.95	105.94	96.59
ME	5.39	26.76	2.33
MD	11.43	42.75	6.87
MA	21.80	54.06	11.93
MI	54.99	95.82	40.50
MN	33.80	22.97	16.69
MS	14.68	12.14	28.79
MO	35.92	47.13	24.45
MT	16.27	5.72	3.34
NE	25.32	5.88	5.63
NV	13.08	2.33	1.68
NH	7.22	9.76	3.36
NJ	42.33	–	21.52
NM	6.62	4.68	21.85
NY	54.85	–	43.53
NY + NJ	–	2753.40	–
Direct_Impact_EXPORT	–	4694.24	–
Direct_Impact_IMPORT	–	6699.90	–
NC	33.14	45.19	22.98
ND	4.87	20.34	1.71

Table 11.4 (continued)

State	LA/LB	NY/NJ	Houston
OH	76.85	165.07	58.15
OK	26.99	24.61	70.97
OR	50.39	24.07	11.05
PA	61.80	247.67	44.13
RI	4.85	4.88	3.35
SC	16.76	33.23	14.49
SD	6.72	8.36	3.44
TN	33.69	28.18	25.43
TX	391.97	345.30	2233.28
Direct_Impact_EXPORT	–	–	3140.82
Direct_Impact_IMPORT	–	–	3219.34
UT	31.76	5.74	11.08
VM	2.41	11.75	1.64
VA	16.98	33.36	15.72
WA	79.50	16.21	17.98
WV	10.58	60.16	13.12
WI	52.77	65.68	28.46
WY	6.52	3.77	7.46
US Total	22766.18	16234.29	9733.92
Rest of World	492.02	589.97	316.02
World Total	23258.21	16824.25	10049.93

state j respectively. These estimates are provided by the procedure used to estimate missing values in the 1997 CFS data. Define IND_{ii} to be diagonal entries in a matrix consisting of IMPLAN's Net Domestic Products (NDP) plus Remaining IMPLAN Foreign Imports for each state i, the double subscript identifies diagonal entries.

$$IND_{ii} = NDP_{ii} + RIFI_i \tag{11.1}$$

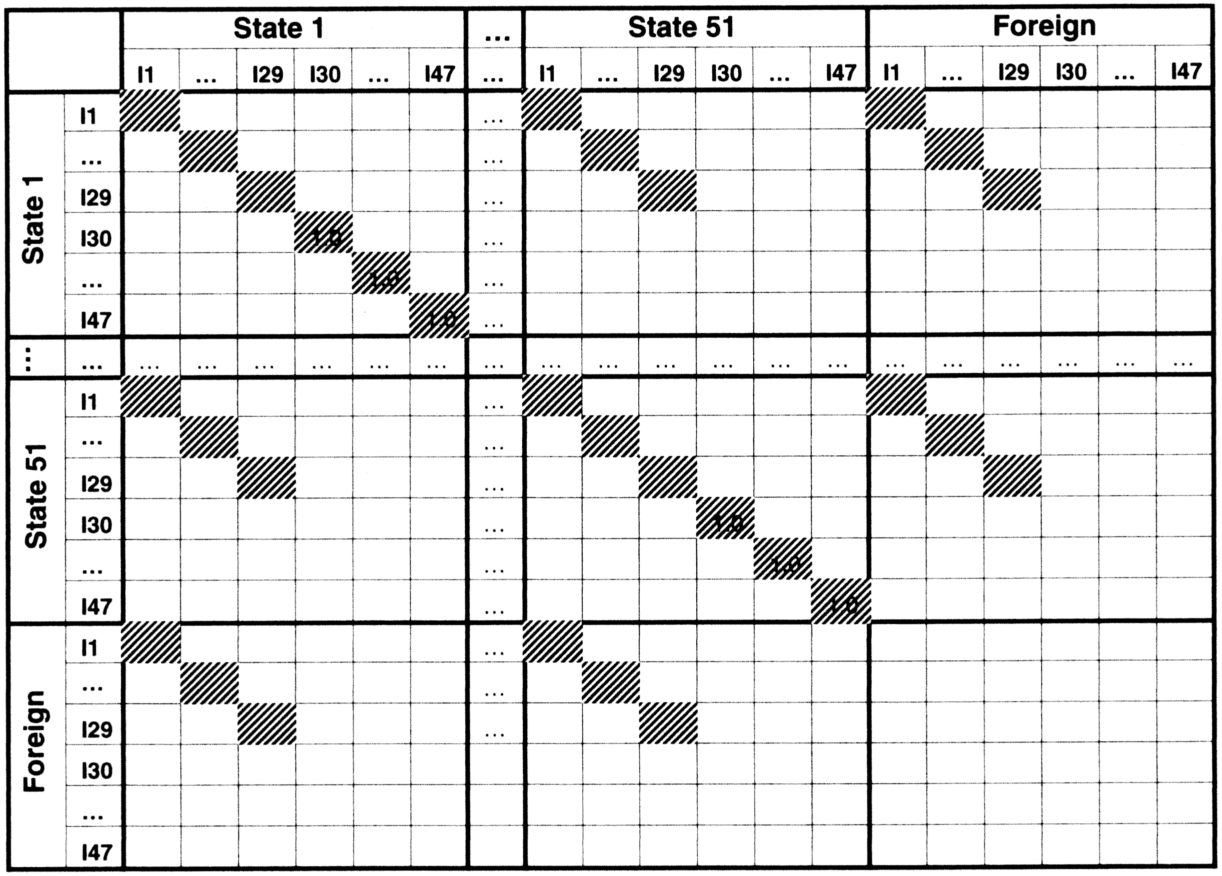
This makes it possible to define the variables shown in equations (11.2.1) through (11.5.2):

$$INTO_i = ITO_i - IFE_i \tag{11.2.1}$$

$$= (IND_{ii} + IFE_i + IDE_i + OIFI_i) - IFE_i \tag{11.2.2}$$

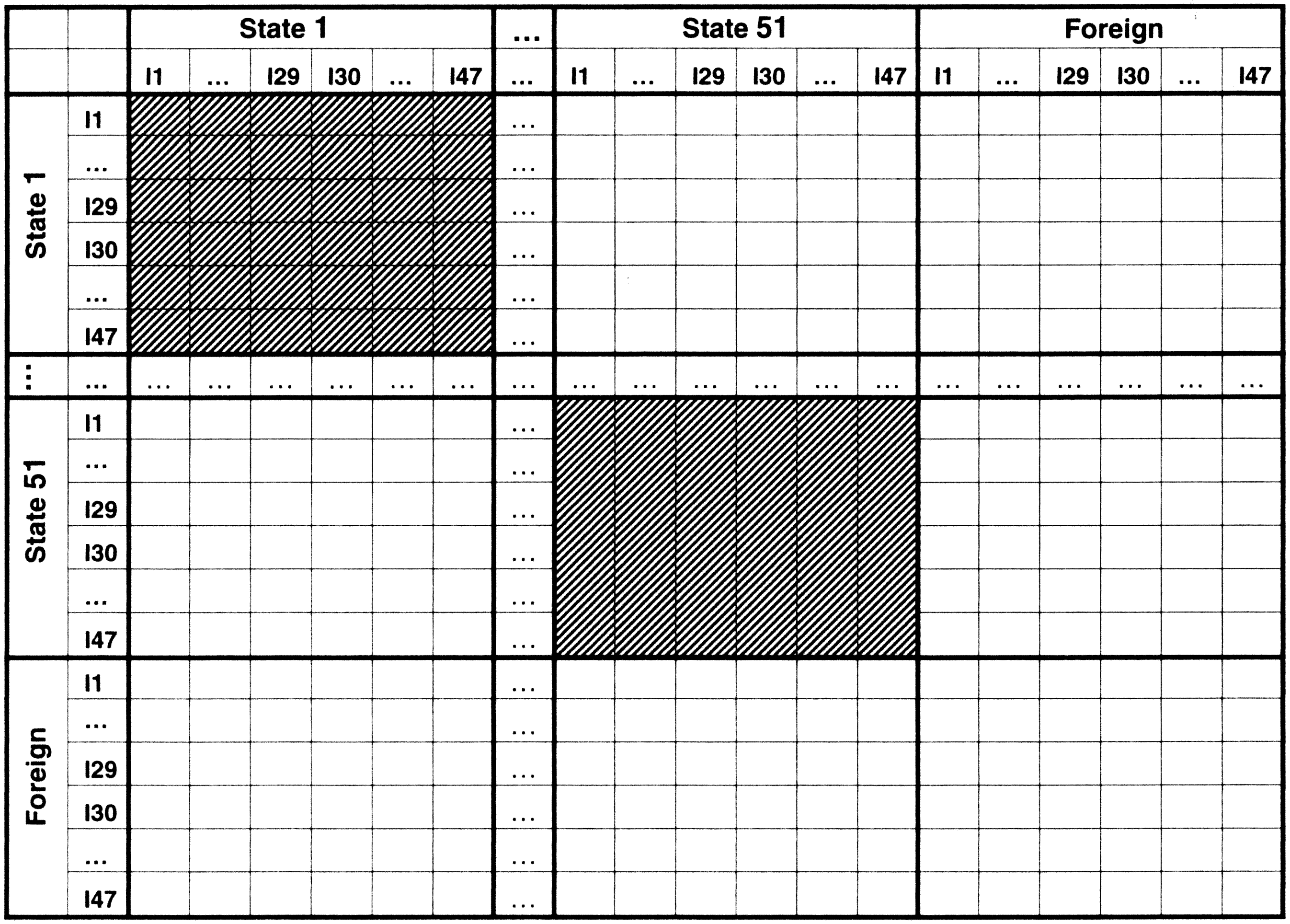
$$= NDP_{ii} + IDE_i + RIFI_i + OIFI_i \tag{11.2.3}$$

$$= NDP_{ii} + IDE_i + AFI_i \tag{11.2.4}$$



Notes:
1. White cells identify zero values.
2. Service sectors have no trade coefficients: Their Diagonal entries are 1.

Figure 11.4 Inter-regional trade coefficients based on commodity trade flows



Note: 1. White cells identify zero values.

Figure 11.5 Inter-industry technology coefficients for 47 USC sectors based on IMPLAN

where: $INTO_i$ = 2001 IMPLAN Net Total (Outputs) Originating in state i;
ITO_i = 2001 IMPLAN Total (Outputs) Originating in state i;
IFE_i = 2001 IMPLAN Foreign Exports from state i;
IDE_i = 2001 IMPLAN Domestic Exports from state i;
$OIFI_i$ = 2001 Outbound IMPLAN Foreign Imports (Transhipped) from state i; and
AFI_i = 2001 IMPLAN Adjusted Foreign Imports to state i.

$$INTD_j = ITD_j - OIFI_j, \qquad (11.3.1)$$
$$= (IND_{ii} + IDI_j + IIFI_j) - IIFI_j \qquad (11.3.2)$$
$$= NDP_{ii} + IDI_j + RIFI_j \qquad (11.3.3)$$

where: $INTD_j$ = 2001 IMPLAN Net Total (Inputs) Destined for state j;
ITD_j = 2001 IMPLAN Total (Inputs) Destined for state j;
$IIFI_j$ = 2001 Inbound IMPLAN Foreign Imports (Transhipped) to state j; and
IDI_j = 2001 IMPLAN Domestic Imports to state j.

We did not account for foreign exports in the estimation of each trade flow in the definitions of $INTO_i$ and $INTD_j$. This is because the foreign exports data in IMPLAN identify foreign exports from each state. This presents two problems. First, it is not possible to separate out the quantities that go to the rest of the world from those that go first to the CFS 'outbound' category and then on to the rest of the world. And second, foreign exports directly to the rest of the world are associated only with the transportation services industry. Therefore, we assumed foreign exports are shipped directly from each state.

Net_INTO_i and Net_INTD_j exclude corresponding diagonal outputs IND_{ii} and IND_{ii}:

$$Net\_INTO_i = INTO_i - IND_{ii} \qquad (11.4.1)$$
$$= IDE_i + OIFI_i \qquad (11.4.2)$$

$$Net\_INTD_j = INTD_j - IND_{jj} \qquad (11.5.1)$$
$$= IDI_j \qquad (11.5.2)$$

Net_ETO_i and Net_ETD_j also exclude corresponding diagonal outputs IND_{ii} and IND_{ii}:

$$Net\_ETO_i = ETO_i - IND_{ii} \qquad (11.6)$$

$$Net\_ETD_j = ETD_j - IND_{jj} \tag{11.7}$$

The growth factors for origin states i and destination states j, G_i and G_j, are calculated from equations (11.8) and (11.9):

$$G_i = Net\_INTO_i / Net\_ETO_i, \tag{11.8}$$

$$G_j = Net\_INTD_j / Net\_ETD_j. \tag{11.9}$$

These growth factors are substituted into equations (11.10) and (11.11) to obtain balance factors L_i and L_j, which are used to update off-diagonal CFS entries iteratively:

$$L_i = \frac{Net\_ETO_i}{\sum_j (MV_{ij}^* \times G_j)}. \tag{11.10}$$

$$L_j = \frac{Net\_ETD_j}{\sum_i (MV_{ij}^* \times G_i)}. \tag{11.11}$$

The observed and estimated cell values MV_{ij}^* for the 1997 CFS data are the starting values to estimate the 2001 CFS off-diagonal flows ij, FV_{ij}^1. This is a standard application of the traditional Fratar model that relies on the calibrated factors provided by equations (11.8) to (11.11):

$$FV_{ij}^1 = MV_{ij}^* \times G_i \times G_j \times \left\{ \frac{(L_i + L_j)}{2} \right\} \quad \text{for all } i \neq j. \tag{11.12}$$

Equations (11.13) to (11.14) define DG_i and DG_j, diagonal entry growth factors for origin states i and destination states j:

$$DG_i = ITO_i / ETO_i. \tag{11.13}$$

$$DG_j = ITD_j / ETD_j. \tag{11.14}$$

Equations (11.15) and (11.16) define DL_i and DL_j, the diagonal entry balance factors used to update the diagonal (intrastate) entries of the CFS matrix iteratively:

$$DL_i = \frac{ETO_i}{\sum_j (MV_{ij}^* \times DG_j)}. \tag{11.15}$$

$$DL_j = \frac{ETD_j}{\sum_i (MV^*_{ij} \times DG_i)}. \qquad (11.16)$$

Estimated Diagonal Values (DV^1_{ii}) are calculated via equation (11.17), which defines a second Fratar model estimating trade flows within each state i. These results also account for new foreign imports remaining within each state:

$$DV^1_{ii} = MV^*_{ii} \times DG_i \times DG_j \times \left\{ \frac{(DL_i + DL_j)}{2} \right\}, \quad \text{for all } i=j. \quad (11.17)$$

These initial estimates of the updated diagonal values, DV^1_{ii}, the diagonal entry growth factors, DG_i and DG_j, and the Diagonal entry balance factors, DL_i and DL_j, are all updated iteratively until they converge to consistent values across equations (11.13) to (11.17).

$$DV^T_{ij} = DV^{T-1}_{ij} \times DG^{T-1}_i \times DG^{T-1}_j \times \left\{ \frac{(DL^{T-1}_i + DL^{T-1}_j)}{2} \right\} \quad \text{for all } i=j. \qquad (11.18)$$

DV^T_{ii} replaces IND_{ii} if and only if $DV^T_{ii} > IND_{ii}$. The final values DV_{ii} replace the diagonal values IND_{ii} in the CFS matrix if and only if $DV^*_{ii} > IND_{ii}$. The 2001 CFS totals for states i and j are reduced by the difference between the corresponding values DV_{ii} and the original diagonal values IND_{ii}.

These initial estimates of the updated off-diagonal CFS flows, FV^1_{ij}, the growth factors for origin states i and destination states j, G_i and G_j, and the balance factors, L_i and L_j, are all updated iteratively until they converge to consistent values across equations (11.8) to (11.12).

$$FV^T_{ij} = FV^{T-1}_{ij} \times G^{T-1}_i \times G^{T-1}_j \times \left\{ \frac{(L^{T-1}_i + L^{T-1}_j)}{2} \right\} \quad \text{for all } i \neq j. \quad (11.19)$$

The stopping rule to identify the optimal values of FV^T_{ij} from equations (11.18) and (11.19) is shown in equation (11.20). The stopping condition is met by maximizing:

$$\sum_i \sum_j FV^T_{ij} \qquad (11.20)$$

subject to:

$$0.999 < (\sum_i Net\_ITO_i / \sum_i \sum_j FV_{ij}^T) < 1.001, \text{ and} \quad (11.21.1)$$

$$0.999 < (\sum_i Net\_ITD_j / \sum_i \sum_j FV_{ij}^T) < 1.001; \text{ or, alternatively,} \quad (11.21.2)$$

$$0.999 < \sum_i \sum_j FV_{ij}^{T-1} / \sum_i \sum_j FV_{ij}^T) < 1.001. \quad (11.22)$$

There is only limited information available about interstate trade in services. The 1977 MRIO inter-regional flow data-set on service sectors is reported to be problematic (Miller and Shao, 1990, p. 1652). Consequently, trade in services between states was assumed to be negligible. Further, given our focus on seaports, we also neglect foreign trade in services. The first step in constructing a NIEMO-type MIRO matrix is to create a set of 29, 52-state-by-52-state trade matrices, one for each of the various commodity sectors; and define 18, 52-state-by-52-state identity matrices, one for each of the various service sectors. These 47 final estimated trade flow matrices are combined into the MRIO format as shown in Figure 11.4. These trade values are producer values. To compare these matrices of estimated trade results with the original CFS trade tables, these producer values must be converted to purchaser values using the appropriate price ratios given in Appendix 1b, available on the CREATE website.

Denote the interstate flows appearing in the 1997 CDS data as V_{ij}. Denote the unreported value of total output originating in state i as TO_i, and the unreported value of total output destined for state j as TO_j. For each state for which 1997 CFS data have been estimated, the ratios, $\Sigma_i V_{ij}/TO_i$ (or $\Sigma_j V_{ij}/TD_j$), are close to unity. Also, referring to the DFM estimates, the state sums of updated trade flows between states ($\Sigma_i FV_{ij}^T$ or $\Sigma_j FV_{ij}^T$) and the IMPLAN total values ($INTO_i$ or $INTD_j$) are also very close to unity. These comparisons provide a basic quality check for the estimates presented here: all these estimates are plausible (Park et al., 2004). Detailed trade flow estimates by USC sectors are available upon request.

Constructing Inter-Industry Trade Flow Coefficients

The 47 USC Sector inter-industry input–output tables were created from the 509-sector 2001 IMPLAN inter-industry table, and then recombined as shown in Figure 11.5. These estimates required some intermediate to steps process the IMPLAN data, and are described in Appendix 6, available on the CREATE website.

ASSEMBLING NIEMO

The NIEMO version of an MRIO coefficient matrix is created by taking the product of the two matrices in Figures 11.4 and 11.5. The model includes no inter-industry data for trade between foreign countries, so the off-diagonal cells representing trade between locations in the rest of the world are necessarily zero. The coefficients for diagonal cells in the foreign-to-foreign region are equal to unity.

The NIEMO inverse matrix can be computed from this product as a special case of the Leontief inverse matrix (= $(I-CA)^{-1}$), as shown in equation (11.23). The structure of this inverse matrix is shown in Figure 11.6. In our applications, we used equation (11.23) to consider the impact of final demand changes, denoted as Y, occurring in any given state:

$$X = (I - CA)^{-1} Y, \tag{11.23}$$

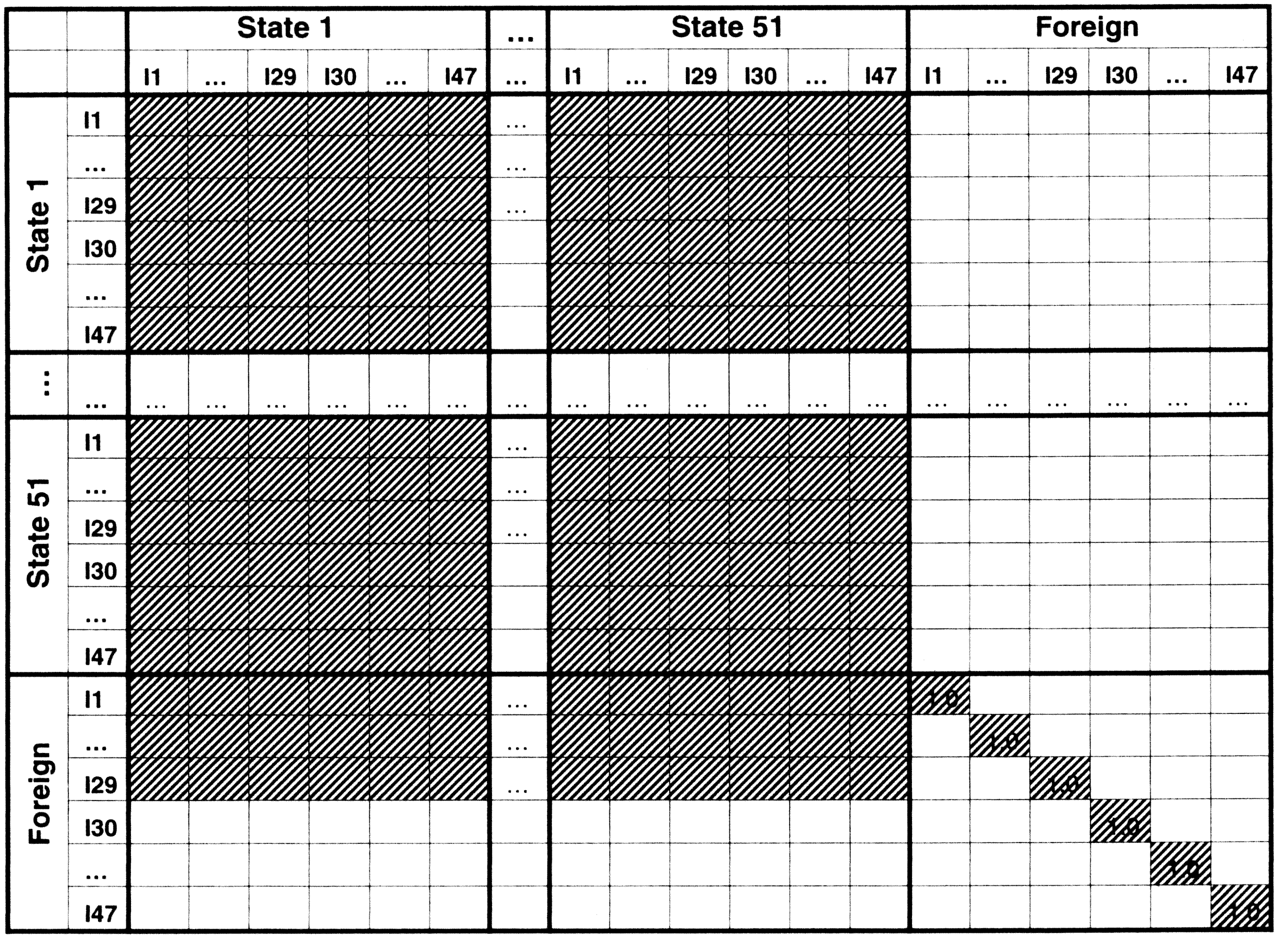
where X = the output vector,
Y = the final demand vector in a particular state,
A = the matrix of inter-industry technology coefficients, and
C = the matrix of interstate trade flows.

NIEMO accounts for the commodity effects of changes in trade within one region on services consumed only within other regions. Therefore, the cross-hatched cells in Figure 11.6 are the only ones that are non-zero.

Because A, C and Y are known, X can be calculated via NIEMO, the vector Y captures projected changes in final demand. For this study, we consider the direct impacts resulting from hypothetical attacks on three major US seaports. The Leontief inverse matrix will consist of $(52 * 47)^2$ = 5,973,136 cells. Given Y^*, hypothesized perturbations defined by interruptions in port services, new outputs X^* are then estimated. All of the required calculations were conducted using the MATLAB™ program.

SEAPORT FINAL DEMAND ESTIMATES

The trade activities by USC Sector for the Los Angeles/Long Beach, New York/Newark and Houston seaports are shown in Table 11.3. These figures are based on the reconciled data above. In the simulations reported here, we assumed that terrorist attacks would close the ports for one month. Because our data are for one year, we created one-month losses by dividing the elements of the sum column by 12. The hypothesized one-month final demand (direct) losses are shown in the fifth (FD LOSS) column. As expected, the



Note: 1. White cells identify zero values.

Figure 11.6 Final interregional inter-industry coefficients: inverse matrix $(I - CA)^{-1}$

LA/LB ports would experience the largest final demand losses ($18.3 billion), while the ports of NY/NJ and Houston incur $11.4 billion and $6.3 billion of direct losses respectively. NIEMO is a linear model and extrapolations to other time periods are straightforward. The caveat is that as the periods studied become longer, the assumption of constant, fixed coefficients becomes more problematic.

As inputs into the NIEMO simulations, FD LOSS data (Y^*) for each port were used as follows. Export losses are presumed to have the standard demand-driven multiplier effects. Import losses are less likely to have such effects and only their direct impacts are included in total effects. It could be argued that the loss of intermediate imports can initiate demand-driven multiplier effects, and that there could be substitutions from other domestic sources. Given the multiple assumptions underpinning this research, we prefer on this point to err on the conservative side. All the results are discussed below.

Because the New York/Newark ports straddle two states, we also tested an alternate 49-state NIEMO model that combines New York and New Jersey. We conducted simulations that compared the results generated by the two versions of NIEMO, with and without the two states combined. The outputs, shown in Appendix 7 available on the CREATE website, demonstrate that the results are approximately the same. This suggests that NIEMO accurately accounts for state-to-state commodity flows, even in circumstances in which flows are as difficult to separate as in the case of NY/NJ.

TERRORIST ATTACK SIMULATION RESULTS

Based on the export final demand losses shown in Table 11.3, the state-by-state indirect impacts from attacks on the three ports were estimated and are summarized in Table 11.4. Aggregate effects vary in direct proportion to port activity. The indirect effects are shown for each state. Direct as well as indirect effects are shown for the states directly impacted. We also include the direct effects of import losses for the states where the attack takes place. Examined from this perspective, multipliers summed across all states range from 1.24 (Los Angeles/Long Beach) to 1.98 (Houston). The differences are accounted for by the fact that LA/LB has the largest value of imports.

A one-month loss of the services of the Los Angeles/Long Beach port costs the US economy approximately $22.8 billion. Corresponding impacts for the ports of New York/New Jersey and Houston are $16.2 billion and $9.7 billion, respectively. If ports are unusable for longer periods, these losses would grow, although strict proportionality would be an overstatement of the impact because substitution options become more feasible and important as time passes. As expected, the overall state-by-state impacts are, in general, a function of state size and distance from the terrorist attack. Similar results are available from NIEMO simulations for all 29 USC commodity sectors (see the CREATE website for examples).

CONCLUSIONS

Several caveats must be attached to our results. We have several reasons to expect that they include both overestimates and underestimates. First, as already mentioned, linear, demand-driven models are more relevant to short-term impact analysis. In the longer run, markets drive a variety of substitutions and price adjustments that the version of the model adopted here cannot account for. Second, it is questionable that a cessation of imports would have demand-driven effects as large as would a cessation of exports. In the previous section, we focused on the full effects of export losses. Only the direct impacts of import losses were included. Third, our analysis omits induced effects transmitted via the household sector. In the short run, households do not adjust their labor force participation rates across state lines. Nevertheless, we believe that we have advanced the state of the art by identifying the approximate orders of magnitude of losses from these types of events.

Also, it is widely accepted that in a federal system, local decision-makers would benefit from information that includes the spatial incidence of losses from various terrorist attacks. Our model has made it possible to estimate these on a state-by-state basis, but for disaggregated intra-regional impacts there are advantages in applying a much more spatially disaggregated (3191-zone) model like the one we have developed for Southern California, SCPM (Southern California Planning Model). Few models with similar degrees of spatial disaggregation have been developed for other metropolitan regions.

NIEMO results have important political implications because the simulations show that the terrorist attacks in one state have significant economic impacts in other states. In the Congress, especially in the Senate where political power is evenly distributed among states, this conclusion could help to garner nationwide support for prevention measures in states where the terrorist threats are more probable even at more distant locations.

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